

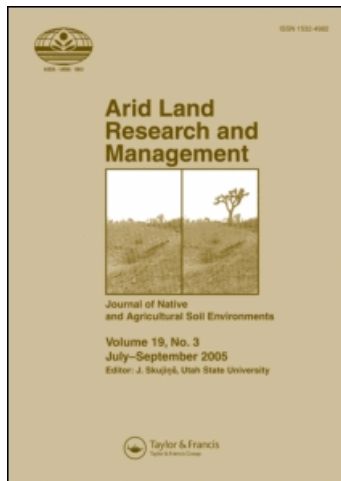
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Rangeland Monitoring and Invasive Weeds

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One of the serious biological obstacles that must be addressed in any comprehensive revision of rangeland ecological condition assessment is what to do with sites dominated by exotic self-invasive species. In certain cases such species have truncated succession so that with a bare minimum of disturbance, the sites will never return to dominance by native perennial species. Are such sites destined to remain always in what is defined as “poor” ecological condition. Many communities dominated by exotic annuals are closed to the recruitment of seedlings of native perennial species. At the same time the communities are open to invasion by other introduced species. Should susceptibility to future invasions be a criteria in assessing the ecological condition of rangeland communities. The sustainability of communities dominated by exotic invasive species is assessing the ecological condition of such communities. Deviation from the plant community concepts of range condition and trend judgement involves setting new benchmark standards. This is an endeavor fraught with many perils.

Keywords self-invasive plants, exotic species, environmental quality, range assessment, secondary succession

When Arthur W. Sampson (Sampson, 1919) first proposed that the plant community growing on a specific range site could be used to interpret the ecological condition of the site, he and virtually all other pioneer range scientists had no inkling that invasive exotic species would become so widespread and dominant on the western range. This universally unforeseen occurrence has profound interactions for assessing the ecological condition of rangelands. Classical range ecology always penalized range condition ratings when exotic species occur in the plant community being assessed. As practiced in the field, the concept was quite simple. Native, presumed climax species were considered excellent. Native species that increased under grazing were not so good. Native species that invaded a community under grazing were very bad and exotic, invasive species were hideous. The less than desirable species increased under grazing because the range was not being properly managed, therefore if the range received proper grazing management the undesirable species, including exotics, would disappear. This simply reflects the laws of plant succession as originally proposed by F. E. Clements (Clements, 1916).

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Cheatgrass

Cheatgrass (*Bromus tectorum* L.) provides an example of the conflicts between traditional assessment of range condition and trend and an exotic invasive species. This annual grass is native to Central Asia (Kostivkovsky & Young, 2000). By prehistoric times it had spread into the eastern Mediterranean Basin and eventually through southwestern Europe and North Africa. It was introduced into much of the New World and spread virtually wherever there was range livestock or winter cereal grain production. This grass was first reported from the farm and range lands of the Intermountain Area of western North America late in the nineteenth century. It was first noted as a weed in cereal grain crops and then as a roadside weed in areas of sagebrush/bunchgrass rangeland (Stewart & Hull, 1949; Yensen, 1981). Gradually, it spread in areas where the perennial grass portion of formerly big sagebrush (*Artemisia tridentata* Nutt.)/bunchgrass [several grasses growing in tufts and forming dense turf] had been severely reduced by prolonged excessive, improperly timed grazing by domestic livestock (Klemmedson & Smith, 1964).

Once it was established and increased in abundance, cheatgrass changed the stand renewal process for formerly big sagebrush/bunchgrass communities by reducing the interval between reoccurring wildfires (Hull & Pechanec, 1947). The fine textured, abundant herbage of cheatgrass increased the chance of ignition and rate of spread of wildfires while extending the duration of the wildfire season into early summer and even late spring (Billings, 1990).

The most important consequence of cheatgrass spread and dominance was through competition for soil moisture; the annual grass inhibited the establishment of seedlings of native perennial species (Harris, 1967; Evans et al., 1970). Through this competition for moisture, the exotic cheatgrass truncated succession (Piemiesel, 1951). The duration and consequences of this truncation were site specific. On sites with higher environmental potential induced by greater rainfall, deeper fertile soils, and often more remnant perennial grasses, the introduction of proper grazing management both in timing of grazing and stocking rates often resulted to a return to perennial grass dominance and eventually a return of woody species to the community. On lower elevation sites with less effective precipitation and virtually no remnant native perennial grasses, the establishment of grazing management only resulted in more cheatgrass fuel to enhance the frequency and severity of wildfires.

West and Hanson (1985) suggested that introduced species are serious concerns only if they became functionally important and/or altered major aspects of structure at the ecosystem level. Cheatgrass would appear to have fulfilled these requirements.

Given the truncation of succession with cheatgrass dominance, the sites are locked into what by definition is "poor" ecological condition. From a theoretical standpoint, the pertinent question becomes what is the nature and divisiveness of the threshold that was crossed with cheatgrass dominance? To restore native perennial grasses, forbs, and shrubs, some form of weed control is necessary to reduce competition from cheatgrass. In addition, the seeding technology must be available to obtain and plant seeds of the native species (Robertson & Pearse, 1946; Young & Clements, 2000). Such conversions are expensive, both for the research necessary to develop the methodology and the implementation of the restoration process on millions of acres of rangeland. Because much of the land where conversion to cheatgrass has occurred is owned by the Federal government, there has to be a groundswell of public opinion in support of such a conversion that would pressure elected public officials to enact legislation funding such programs. On privately owned rangelands infested with cheatgrass, the ranchers must see a demonstrable economic advantage if conversions from cheatgrass to perennial grass dominance is to be initiated. Therefore, the threshold that was crossed with cheatgrass dominance is as much social and political as it is biological. If society is not willing to pay the cost for conversion from cheatgrass range back to dominance by perennial species, is

the cheatgrass dominated range in “poor” phyto-sociological condition or is the American society in poor ecological awareness condition?

Sustainability

Despite frequent comments that cheatgrass only furnishes forage for a couple weeks in the spring or that cheatgrass is not eaten by herbivores, native or domestic, the nutritive value and livestock preference for the forage was clearly demonstrated by qualified scientists by the mid twentieth century (Fleming et al., 1942). Forage production by cheatgrass stands is highly variable among years. The forage production of native perennial grasses also is highly variable among years, but on dry years the native perennials usually produce some forage while cheatgrass seeds may not germinate or the seedlings may fail to establish (Young et al., 1969). This has long been considered as a significant disadvantage to basing livestock production on cheatgrass (Stewart & Young, 1939). Certainly, the native perennial grasses produce some forage during the dry years, but should these drought-stressed plants be grazed during the growing season? The classic downplaying of cheatgrass as a forage plant in comparison to native perennial grasses seems to be at least somewhat suspect.

The major drawback of cheatgrass as a forage resource is the ease with which it ignites and burns. Good managers can leave a reserve of standing dry cheatgrass forage for winter grazing or for emergency use if the next season is exceptionally dry. This is very prudent management except such forage reserves are one spark away from disaster (Young et al., 1987).

Arguments about the pros and cons of cheatgrass as a forage species will undoubtedly continue, but the critical question is, especially as it pertains to assessing the ecologic condition of rangelands, are cheatgrass ranges a sustainable resource? We have previously stated that cheatgrass seedlings can outcompete seedlings of native perennial species for moisture for seedling growth. In a temperate desert environment such as the Great Basin of western North America, moisture is the paramount factor influencing seedling establishment, but available nitrogen is a catalyst that governs competition for this resource (Young et al., 1996). Available soil moisture and soil nitrogen obviously interact in governing the competitive relations of cheatgrass and seedlings of perennial species.

Cheatgrass thrives on abundant available nitrogen (McLendon & Redente, 1992). Fertilization with nitrogen of a mixed stand of perennial bunchgrass and cheatgrass resulted in the death of the perennial grass. Reducing available nitrogen by immobilization or the inhibition of nitrification, results in the temporary disappearance of the annual grass from degraded communities (Young et al., 1997). Nitrogen is typically found in very small amounts in temperate desert communities, however, many of the native plant species can establish and reproduce under extremely meager levels of nitrogen (Eckert et al., 1970). Wildfires and soil disturbance associated with excessive grazing lead to bacterial mineralization of nitrogen as opposed to fungal mineralization of nitrogen in native plant communities. Is continued cheatgrass dominance producing a mining of nitrogen that will eventually deplete the resource? In ancient agricultural ecosystems such as the oak (*Quercus* sp.) woodlands in southwestern Spain, more than two millennia of farming and grazing have depleted soil nitrogen levels to the point that cheatgrass is found on bed grounds for sheep only (Young & McKell, 1976). What will happen to cheatgrass populations when nitrogen is exhausted? Probably, after a prolonged period of time, cheatgrass would exhaust the mineralizable nitrogen on specific sites. Therefore, on a long term basis cheatgrass is not a sustainable grazing resource. This is probably a moot point because cheatgrass communities that are closed to the establishment of seedlings of native perennials are notoriously open to the establishment of other exotic, invasive species.

Succession Among Invasive Species

One of the strange paradoxes of secondary succession is that invasive plant communities that truncate succession and largely inhibit the establishment of seedlings of high seral native plants are themselves notoriously susceptible to invasion by seedlings of other exotic, invasive species. In degraded big sagebrush/bunchgrass communities the first exotic species to invade is Russian thistle (*Salsola targus* L.) (Young et al., 1972). It is usually replaced the next year by tumble mustard (*Sisymbrium altissimum* L.), another exotic, invasive species. The final stage in this secondary succession is cheatgrass (Piemesel, 1951). Destroy the cheatgrass and succession will regress to the lower successional levels (Young et al., 1969). There are many variations to this simplification of the secondary succession among exotic annuals. Probably the first exotic annual to be introduced to big sagebrush environments is red stem filaree [*Erodium cicutarium* (L.) L'Hér] (Young et al., 1975). It is apparently the only introduced annual that was extensively, consciously disseminated by humans as a forage species. Occasionally it is a transitory dominant on specific sites. Another early introduction that remains an occasional species in the secondary succession on formerly big sagebrush/bunchgrass rangelands is prickly lettuce (*Lactuca serriola* L.) (Hillman, 1897). The prime example of how open to invasion cheatgrass dominated communities can be is furnished by the diminutive annual bur buttercup (*Ranunculus testiculatus* Crantz) (Young et al., 1992). By being an extreme ephemeral species, it germinates, flowers, and produces seeds in the very early spring, apparently without competing with cheatgrass. The competitive gamesmanship among annual species within cheatgrass dominated communities is demonstrated by the dynamics initiated with the invasion of a second species of *Salsola*, barbwire Russian thistle (*S. paulsenii* Litv.) (Young & Evans, 1978). For rangeland communities in the Great Basin, the introduction of this exotic species virtually eliminated Russian thistle from successional communities and greatly reduced the presence of halogeton [*Halogeton glomeratus* (M. Bieb.) C. Meyer] on disturbed soils in big sagebrush communities (Young et al., 1999). There is a decided tendency to lump all cheatgrass infested ranges together as a single uniform type. The successional process that leads to cheatgrass dominance may be initiated by Russian thistle, barbwire Russian thistle, or halogeton colonization of disturbed sites. The next stage in succession is often tumble mustard, but occasionally it is the native tansy mustard [*Descurainia pinnata* (Walter) Britton] or the exotic shield cress (*Lepidium perfoliatum* L.). Depending upon site potential, cheatgrass dominated communities may share dominance with a variety of other exotic annuals. Therefore, site potential in terms of soils and climatic conditions that influence plant growth and soil development are important in determining the ecological condition of cheatgrass communities as well as native plant communities. Random sampling in cheatgrass dominated communities without some intelligent stratification based on site potential will increase sample variability to the point that precision is lost.

Medusahead

The introduction and dominance of the annual grass medusahead [*Taeniatherum caput-medusae* (L.) Nevski] is probably the most visible example of the fragility of the successional dominance of cheatgrass on rangelands (Young, 1992). Medusahead was introduced to western North America somewhat later than cheatgrass. It is well established in California, Oregon, Washington, and Idaho, with outlying populations in Nevada and Utah. It represents a stage in exotic annual succession beyond cheatgrass. This can be clearly demonstrated by applying a nonselective herbicide that kills medusahead and allows replacement by cheatgrass (Young & Evans, 1972). If you then till the site, Russian thistle will become the dominant, followed by tumble mustard, cheatgrass, and eventually medusahead again. Medusahead has only very

limited forage value for livestock and the seeds are not preferred by granivores. Despite being the greatest silicon accumulator of any grass, medusahead standing dry herbage and litter are an extremely hazardous fuel for wildfires (Young, 1992). It is even more of a risk for wildfires than cheatgrass. In the Great Basin, not all sites that support cheatgrass are capable of supporting medusahead. Medusahead appears to prefer soils with higher clay contents (Young & Evans, 1970). It has been suggested that the species is more competitive on clay soils because of their higher moisture holding capacity compared to coarser textured soils. Medusahead apparently needs this extra moisture because it matures two to four weeks later than cheatgrass. This is true for some, but not all accessions that have been compared in common gardens (Young et al., 1970).

These successional considerations lead to some difficult decisions when assessing the ecological condition of a given range site. Under most procedures that are being used, a site which originally supported a big sagebrush/bunchgrass community and is now dominated by cheatgrass is automatically in poor ecological condition. If the site is producing usable forage for the foreseeable future, even though we are reasonably certain that cheatgrass will eventually, on some indefinite time scale, exhaust supplies of nitrogen, what level of ecological condition is applicable under some new and not yet defined systems of values? Let's look at this problem from the aspect of rangeland health and functioning ecological systems. Proper levels of grazing leave litter cover on the soil surface on this hypothetical range site. Moderately grazed cheatgrass ranges have more litter cover, both in amount and uniformity of cover, than comparable native bunchgrass communities on the same site. Therefore, accelerated erosion is not apparent. Probably, as much or more carbon is being fixed as when the site supported native perennial plants (Hinds, 1975). Litter decay is taking place, so nutrient cycling is functioning. The archaic notion that cheatgrass is a very shallow rooted species has been found to be false (Hulbert, 1955; Harris, 1967). Cheatgrass roots use moisture and nutrients as much or more than the roots of the big sagebrush/bunchgrass community that preexisted on the site. Nutrient cycling is probably much more rapid and certainly more uniform in a cheatgrass dominated community compared to a degraded big sagebrush community where shrubs mine the interspaces for nutrients and moisture and concentrate their litter fall in subcanopy areas (Charley & West, 1975). Is this functioning cheatgrass community in good or even excellent ecological condition?

The ecologically functioning cheatgrass ecosystem is just a spark away from being consumed in a wildfire. Catastrophic stand renewal in wildfires was present in the original community, so what is novel about cheatgrass fires? The interval between burning and the relative characteristics of the wildfire are critical issues. Estimates for the interval between wildfires in pre-European contact with the Great Basin vary from less than five to more than 100 years for specific sites (Blaisdell, 1953). Wildfires on sagebrush rangelands induce physical and biochemical changes to the surface and at least the top horizons of the soil profile (Blank et al., 1994). In the absence of accelerated erosion, how bad an effect do frequent cheatgrass fueled fires have on ecological function of a community? To assess ecological condition of a given range site under these conditions, you have to start setting benchmark values, but there is no or little hard science for the justification of target values.

Let us postulate two cheatgrass dominated communities on what were formerly big sagebrush/bunchgrass range sites. One site is at the lower level of the big sagebrush zone with a sandy textured soil and limited precipitation. The other site is located at higher elevation with more precipitation, and a clay-loam surface soil, and a well developed argillic horizon. Medusahead is already established in the vicinity of both communities. Are both communities in the same level of ecological condition or does the threat of medusahead invasion place the higher elevation site in a lower ecological condition class? Past assessments of the ecological condition of rangelands have evaluated what has happened in terms of successional change. When dealing

with invasive, exotic species, is what is going to happen in future succession a valid factor in the assessment of ecological condition? Again, the application of radically revised condition classes is all in the setting of benchmarks.

Beyond Exotic Annual Grass Dominance

B. F. Roche, Jr. was probably the first to point out that we are living in a fools paradise with cheatgrass dominance of formerly big sagebrush/bunchgrass rangelands (Roche & Roche, 1988). Annual grass dominance is a passing stage to dominance by exotic biennial or eventually perennial species. The diversity of cheatgrass and medusahead communities is increasingly being enhanced by broad-leaved exotic annuals. Perhaps, the most important of these species is yellow starthistle (*Centaurea solstitialis* L.). In the drier portions of the range of medusahead, on the margins of the Great Basin and in the Columbia Basin of Oregon, Washington, and Idaho, there is a great affinity for medusahead and yellow starthistle to occur on the same sites together. This is a case of noxious weeds in the legal sense forming a very obnoxious community for animals including humans.

A large number of biennial species establish and partially suppress cheatgrass and medusahead. These include dyer's woad (*Isatis tinctoria* L.), skeleton weed (*Chondrilla juncea* L.), Scotch thistle (*Onopordum acanthium* L.), Mediterranean sage (*Salvia aethiopis* L.), musk thistle (*Cardus nutans* L.), and bull thistle [*Cirsium vulgare* (Sari) Ten.]. Of this group, musk and bull thistle are primary species of wet meadows and only mingle with the exotic annual grasses on the margins of such sites. The others are nasty upland weeds that are found invading many different sites, but rarely reach the landscape dominance associated with cheatgrass or medusahead. There is a transitory life habit group some of which can be annuals, biennials, or short-lived perennials. To this group belong diffuse knapweed (*Centaurea diffusa* Lam.), spotted knapweed (*C. maculosa* Lam.), and Wilson weed [*Brassia elongata* ssp. *integrifolia* (Boiss.) Breistr.]. This flexible life style apparently brings competitive advantages.

Almost all of the perennial exotic, invasive weeds that are widely distributed in degraded big sagebrush/bunchgrass communities have either rhizomes or creeping root stocks. Canada thistle [*Cirsium arvense* (L.) Scop.] infestations are usually associated with the margins of agronomic fields and wet meadows. Hoary cress or white top [*Cardaria draba* (L.) Desv.] is a variable complex sometimes treated as three separate species. In the Great Basin, it was an early introduction, and in old mining towns it is often the principle vegetation of vacant lots and waste areas. It is a highly persistent, very difficult to control weed of cropland and native meadows. In the Great Basin, hoary cress is the most frequent and most abundant exotic perennial invasive species in even very remote stringer meadows that have interrupted distributions along seasonal water courses on mountain escarpments. In northeastern Oregon east of Baker City, there are extensive areas of clay-textured soils occupied by a community composed of medusahead, yellow starthistle, and what is identified as hoary cress. The upland semiarid nature of these communities is highly out of character for typical hoary cress, but their existence is of sufficient scale to be considered landscape characterizing.

Perennial pepperweed (*Lepidium latifolium* L.) is also known as "whitetop" or tall whitetop. It is a much more recent introduction to the Intermountain region (Young et al., 1995). The results of infestations of this species are much more devastating on the environment than those associated with hoary cress. Perennial pepperweed is a much taller, semiwoody species that comes close to forming complete monocultures. In the past, infestations of perennial pepperweed have been associated with wetlands, riparian areas, irrigated fields, and native hay meadows. Increasingly, perennial pepperweed colonies are found in ruderal environments in the heart of rangeland environments, even in harsh salt desert environments.

Reaching across the northern tier of states from the Dakotas to Washington state, rangelands from prairie grasslands to big sagebrush communities have been invaded by leafy spruce (*Euphorbia esula* L.). The distribution of this species reaches down into the aridity of the Great Basin environment as spot infestations on specific, often wetter environments. It has not become a landscape characterizing species in the more arid areas where cheatgrass or medusahead are the dominant species.

Squarose knapweed (*Centaurea squarrosa* Willd.) is the odd perennial exotic invasive species of exotic annual grass communities. It is a taprooted rather than creeping rooted species. The last perennial species to be discussed is Russian knapweed [*Acroptilon repens* (L.) DC.]. This weed was introduced to North America in the late nineteenth century. Its very wide distribution in western North America probably is the result of it being a contaminant of alfalfa (*Medicago sativa* L.) imported from Central Asia. In the drier portions of the Intermountain Area, infestations of this pest often consisted of small highly stable spots that were impossible to eradicate, but not highly invasive. In agronomic fields, tillage spread the root stocks and nasty, highly persistent infestations seriously interfered with crop production. Russian knapweed is a self-incompatible species that must be cross-pollinated by insects. Perhaps, infestations suddenly reached some critical level where pollination and therefore sexual reproduction was possible. This may have led to recombinations that are more adapted to semiarid to arid growing conditions. Whatever the cause, the result has been far-reaching expansions of Russian knapweed populations to temperate desert areas far remote from irrigated agriculture. At such locations Russian knapweed is expanding populations from roadsides to degraded big sagebrush/bunchgrass or degraded shadscale [*Atriplex confertifolia* (Torr. & Frém.) S. Watson]/Bailey greasewood (*Sarcobatus baileyi* Coville) communities currently dominated by cheatgrass. Is this the future for vast areas of rangeland currently dominated by cheatgrass? If so, how will such changes be incorporated in future ecological range condition assessments?

Check the botanical authority for the successful exotic, invasive weeds that have found a home in former big sagebrush/bunchgrass rangelands. A surprising number were first described by Linnaeus. Halogeton is a notable exception, but most of these weed species have been around humans for a long time. Dyer's woad, which was a mediaeval and colonial American crop plant, may be the origin of the word weed (Young et al., 1971). These plants have an affinity for environments associated with human activities.

Inherent Potential

Quite early in his brilliant career as an ecologist in the Pacific Northwest, Rexford Daubenmire (Daubenmire, 1940) reported that the exotic annual grass, cheatgrass, had successfully invaded and maintained population in bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh) A. Löve] dominated communities, and that because of the location on inaccessible buttes had never been grazed by domestic livestock. He interpreted this as evidence that native plants, especially highly competitive annuals, never evolved in the sagebrush/bunchgrass communities to fill the environmental niche occupied by cheatgrass. Neil West has pointed out that the extreme abundance and competitive vigor of big sagebrush seedlings made it very difficult for herbaceous annuals to evolve in big sagebrush/bunchgrass communities (West & Hanson, 1985).

In many ways, the exotic invasive species that have become so dominant on Intermountain rangelands have been exploiting a natural biological near vacuum that was greatly enhanced by the activities of humans and their domestic livestock (Young et al., 1972). The biggest hurdle to appreciating the role exotic species play in former big sagebrush/bunchgrass rangelands is the widespread assumption that the plants that have evolved on a site are genetically those most adapted to the site as it

exists today. The genotypes that existed on a given site at European contact time were mere accidents of segregation and chance dispersal (West, 1991). There is no way that all of the genetic differences within a given species would have had the opportunity to disperse to each site where examples of the species exist. It is a difficult assumption for many would-be ecologists to accept, but cheatgrass may be the most adapted and most adaptable herbaceous species on formerly big sagebrush/bunchgrass rangelands.

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